Studies on the Reproductive Biology of Pacific Cod and English Sole in Hecate Strait from the Cruise of the *FR/V W.E. RICKER*, November 25-29, 1986

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STUDIES ON THE REPRODUCTIVE BIOLOGY OF PACIFIC COD AND ENGLISH SOLE IN HECATE STRAIT FROM THE CRUISE OF THE FR/V W.E. RICKER, NOVEMBER 25-29, 1986

by

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ABSTRACT

Tyler, A. V., J. Fargo, R. P. Foucher, and J. B. Lucas. 1987. Studies on the reproductive biology of Pacific cod and English sole in Hecate Strait from the cruise of the FR/V W.E. RICKER, November 25-29, 1986. Can. MS Rep. Fish. Aquat. Sci. 1937: 43 p.

The cruise reported on here is part of a series of cruises designed to investigate the reproductive biology of Pacific cod and English sole. The objective of the program is to document spawning timing and location, the rate of oocyte development, and whether spawning timing depends on size of fish, water temperature, or stock density. We will determine during the program whether there are differences in response between the Hecate Strait stock and the LaPerouse stock. We are also investigating fecundity, and whether there are changes in fecundity with similar factors. The investigation of maturation cycle is being carried out through histological preparations and ovary weighing. Fecundity is being investigated by freeing oocytes from ovarian tissue and counting subsamples. Findings reported on include length-frequency distributions, percentage mature ogives, length-weight data, and ovary weight-fish weight data. Pacific cod ranged from 25 cm to 51 cm, and showed modes at 29 cm and 40 cm. There were too few mature Pacific cod taken to determine the median size at maturity, and the relation between ovary weight and body weight was also indeterminate for fish larger than 1 kg, though there was a positive slope for immatures. English sole ranged from 16 to 48 cm. Median size at maturity was 34.3 cm. The relationship between ovary weight and body weight was linear, with an overall mean ovary weight of 5.5 g corresponding to a mean body weight of 601 g.

RESUME

Tyler, A. V., J. Fargo, R. P. Foucher, and J. B. Lucas. 1987. Studies on the reproductive biology of Pacific cod and English sole in Hecate Strait from the cruise of the FR/V W.E. RICKER, November 25-29, 1986. Can. MS Rep. Fish. Aquat. Sci. 1937: 43 p.

L'expédition décrite dans le présent document fait partie d'une série d'expéditions conçues pour étudier la reproduction de la morue du Pacifique et de la sole anglaise, en particulier pour établir le moment et l'endroit de la fraie, le taux de développement des oocytes et si le moment de la fraie dépend de la taille du poisson, de la température de l'eau ou de la densité du stock. Les auteurs tentent aussi de déterminer s'il existe des différences de réaction entre le stock du détroit d'Hécate et celui du banc LaPérouse. De plus, ils étudient la fécondité et sa variation potentielle en fonction des facteurs susmentionnés. Des préparations histologiques et la détermination du poids ont servi à l'étude du cycle de maturation des ovaires tandis que la fécondité a été établie à partir du dénombrement de sous-échantillons d'oocytes libérés du tissu ovarien. Les auteurs présentent des distributions de la fréquence des longueurs, les pourcentages d'ogives matures, les relations longueur-poids et des données sur le poids des ovaires en fonction de la longueur des poissons. La longueur de la morue du Pacifique, qui va de 25 à 51 cm, montre des modes à 29 et 40 cm. Le faible nombre de morues du Pacifique matures capturé n'a pas permis de déterminer la taille médiane à la maturité tandis que la relation entre le poids des ovaires et le poids corporel était imprécise pour les poissons de plus de 1 kg; par contre, le graphique des données sur les poissons immatures montrait une pente positive. La longueur de la sole anglaise va de 16 à 48 cm, avec une longueur médiane de 34,3 cm. La relation entre le poids des ovaires et le poids corporel est linéaire; un poids des ovaires moyen total de 5,5 g correspond à un poids corporel moyen de 601 g.

INTRODUCTION

This cruise is the first in a series to investigate aspects of the reproductive biology of Pacific cod and English sole. These two species are important components of the multispecies trawl fishery in Hecate Strait. Strong fluctuations in abundance of Pacific cod are due to interannual variation in recruitment (Tyler and Westrheim, in press). The interannual fluctuations in abundance of English sole are not so pronounced, but occasionally, exceptionally strong year-classes dominate the stock and the fishery (Fargo 1985). It is necessary to understand the factors causing these fluctuations in order to make accurate predictions concerning recruitment to improve stock assessments for the two species. Biologists need to distinguish between declines caused by the fishery and declines caused by nature.

There is evidence that Pacific cod year-class strength is influenced by temperature during the egg-incubation period, and variation in the strong, northward current while the fish are in their egg and larval stages. A density-dependent parental effect has also been demonstrated (Tyler and Westrheim, in press). English sole year-class strength is, in part, related to time of spawning, and also to advection from nursery areas while fish are in their egg and larval stages (Ketchen 1956, Kruse 1984). Studies carried out during the 1970s off the coast of Oregon indicated that time of spawning was influenced by the annual temperature regime (Kruse and Tyler 1983). The temperature regimes are so different between Hecate Strait and Oregon, however, that a comparison of English sole recruitment in the two areas should prove to be a powerful way of understanding the factors influencing recruitment for the species.

The first objective of this investigation is to develop a monthly time-series for examination of the maturation cycle through histological preparations of the ovaries. The series will allow investigators to relate physical oceanographic factors to time of spawning and reproductive success. Pacific cod and English sole are cohabitants, and the same cruises can be used to gain information for both species.

The second objective is to gain information on interannual variation in size at maturity, and fecundity. There are indications that fluctuations in size at maturity do occur in Pacific cod (Foucher and Welch, in prep.).

The third objective is to develop a sub-sampling plan for mixed species catches so that unbiased estimates of total catch and length composition can be made without measuring every fish. The new conveyer equipment on the W. E. RICKER may facilitate increased efficiency in sampling.

MATERIALS AND METHODS

Two areas were selected for fishing: White Rocks and Horseshoe grounds (Fig. 1). The positions for the trawl hauls were selected from previous groundfish cruise reports of the Pacific Biological Station. It was anticipated that both species would be available in these areas. Also, the areas are spaced widely enough apart so that a test for homogeneity in the data could be made with regard to latitude.

The vessel employed was the FR/V W.E. RICKER, fishing a 145 Engel trawl with a 96-ft headrope and a 145-ft footrope. The net was fished with the ship's 1-tonne, oval, steel doors used with 50-meter sweeps. The warp consisted of 1 1/8-inch, steel cable. The net mesh sizes were: 7-inch in the wings, 6-inch in the square, 5-inch in the belly and, 3-inches in the codend. There were 15 steel floats on the headline and the groundline had 14-inch rubber bobbins in the bosom section, and 6-inch, rubber disks in the wing sections (Fig. 2).

The entire catch was dumped into the fish hopper leading to the fish-handling laboratory below deck. All Pacific cod and English sole were sorted from the conveyer belt and separated into plastic baskets. Approximately half of the juvenile sablefish from the first set were set aside in the same way. All fish set aside were measured for fork length to the nearest cm. The sablefish were measured without determination of sex. English sole and Pacific cod were measured as males, immature females, and mature females. English sole caught in haul 3 were not sampled due to time constraints.

Length, sex, and maturity data were recorded, and selected, individual fish were weighed (with stomachs emptied), and their ovaries removed and weighed. In the case of Pacific cod, both ovaries were removed, while for English sole only the right ovary was removed. Ovaries were preserved in buffered formal saline for later processing. The sampling schedule used for the cruise is listed in Table 1. A length-stratification procedure was used to ensure that samples were spread throughout the anticipated length range of each species.

The length-maturity relationship was calculated for English sole but not for Pacific cod due to the small number of mature Pacific cod captured.

Length-weight relationships were estimated for English sole and Pacific cod females based on the samples of fish selected for the histological study. Non-linear fitting methods were used to fit the data to the equation $W=aL^b$ where W= weight in grams and L= length in cm.

Temperature profiles by depth were taken with an XBT.

RESULTS

Three hauls were made on November 27 near White Rocks (Appendix table 1). The first two were 20 minutes in duration, but the third lasted only 9 minutes. At that time the main trawl winch malfunctioned, and the rest of the cruise had to be aborted. Positions of the trawl hauls are given in Figure 1. A total of 1059 English sole, 549 Pacific cod and 523 juvenile sablefish were measured. Length-frequency data collected for English sole included 312 males, 288 immature females, 111 mature females, 341 females not identified as to maturity, and 7 fish not identified as to sex. Length-frequency data collected for Pacific cod included 185 males, 201 immature females, 4 mature females, and 159 fish measured without reference to sex or maturity.

English sole length frequencies are summarized for males, females, and sexes combined in Figs. 3-5, respectively. Mean lengths were 24.0 cm for males and 30.2 cm for females. The dominant length mode in all samples represents the 1985 year-class of English sole. Approximately 70% of the total catch of English sole for the cruise consisted of females. It is also interesting to note that less than 1% of the English sole males in the catch were larger than 35 cm, the minimum size for English sole accepted by the B.C. fish processing plants.

Pacific cod length frequencies are summarized for males, females, unsexed, and combined samples in Figs. 6-9, respectively. Mean lengths were 36.0 cm for males and 37.6 cm for females. The dominant length modes in all samples represent the 1985 and 1986 year-classes. The sex ratio for Pacific cod caught on the cruise was nearly 1:1.

A maturity ogive for English sole females is presented in Figure 10. The ogive was produced from a sample of 399 English sole females identified with regard to maturity. The smallest mature specimen was a 25-cm fish while 50% of the fish at 34 cm were mature and 100% of the fish of 40 cm or larger were mature.

Ketchen (1956) reported that 50% of the English sole females in Hecate Strait were mature at age 4 (mean length 34 cm) while 100% were mature by age five or six (mean length 38 cm).

No maturity ogive was constructed for Pacific cod due to a lack of mature fish in the samples.

A sample of English sole taken for histological analysis was nearly completed (Table 2 and 4). The sample lacked only two immature fish at the largest immature size-category, and one fish in the largest mature size-category. Only one of the mature fish had ovaries ready for spawning, the others were spent. Because of this a sample of English sole for fecundity studies was not obtained.

The relationship between English sole ovary weight and body weight is shown in Figure 11. The relationship is linear and appears to be the same for immature and mature fish.

The relationship between body weight and fork length for English sole females is presented in Figure 12. Coefficients for the regression equation $W=aL^b$ were a=0.0154 and b=2.87. The coefficient of determination for the regression was 0.98. Coefficients previously estimated for English sole females at White Rocks were a=0.00512 and b=3.16 (Fargo et al. 1984). The size range was 20-47 cm (176 fish) while the size range for this experiment was 27-47 cm (75 fish).

Sampling of Pacific cod was incomplete. As with English sole, there was no sample taken for fecundity studies. The reason, however, was entirely different. Insufficient numbers of mature cod were found in the hauls. The histological sample required for immature cod was completed with 15 fish in each size category (Table 2 and 5). Only 7 of the 80 mature fish required for the histological sample were caught, however, we have little doubt that if the cruise had been completed the samples would have been obtained. Three of the seven mature Pacific cod had late-ripening ovaries. The other four were just developing large arteries and opaque, buff-coloured eggs. Fin rays for age determination of the cod were not taken because all fish were at the small sizes that can be assigned ages by the length-frequency-analysis technique (Foucher and Fournier 1982).

The relationship between Pacific cod ovary weight and body weight is shown in Figure 13. Different relationships are observed for mature fish and immature fish. Significantly different ovary weights observed for body weights of 1000g reflect fish at different maturity stages. Too little data was collected to ascertain the exact nature of the relationships here.

The regression coefficients a and b for the equation $W=aL^b$ for Pacific cod females were a=0.00240 and b=3.39. Previous work (Westrheim 1977) for Pacific cod in Hecate Strait had estimated coefficients for females of a=0.00738 and b=3.10. The length-weight relationship developed here (Fig. 14) is not considered as reliable as the previous relationship due to a lack of fish at the larger sizes.

A temperature profile for the White Rocks area was taken during haul 1 and is summarized in Table 3. The ocean surface temperature was 9.1°C as compared to a November monthly mean surface temperature of 8.6°C taken at the adjacent Bonilla lighthouse for the period 1960-1985. Conditions were isothermal (8.9°C) from 20 meters to the ocean bottom (84 meters).

SECONDARY OBJECTIVES

The plan to carry out experimental subsampling of the catch was aborted due to winch failure.

SPECIAL REQUESTS

Ten, mature, female English sole were dissected and the left ovary frozen for Dr. Garth Fletcher at Memorial University in St. Johns, Newfoundland. These samples were needed as part of a study of the genetic basis for the production of antifreeze in the Pleuronectidae.

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We thank A. Ranger, Master; A. Fletcher, Fishing Master; R. Dillon, Chief Engineer; and the officers and crew of the FR/V W. E. RICKER for doing their best at getting the cruise off despite the operational uncertainties brought about by the newness of the ship.

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Table 1. Sampling schedule for reproductive-biology cruise for Pacific cod/English sole.

All female English sole and Pacific cod will be sampled for LENGTH, FISH WEIGHT, OVARY WEIGHT, and AGE

English sole

One sample (collection) of each type given below will be made for the whole of Hecate Strait as the locality.

Pre-cruise estimated length at 50% maturity = 34 cm (Ketchen, 1956)

Fecundity sampling:

The length range to be sampled is 30 - 50 cm (20-cm range)
Total sample: 100 fish for the whole of Hecate Strait
Stratification: 10 fish per 2-cm interval from 30 - 50 cm

Histology sampling:

The length range to be sampled is 20 - 50 cm (30-cm range)
  immature fish: 20 - 40 cm
  mature fish: 30 - 50 cm
Total sample
  immature fish: 20 fish
  mature fish: 60 fish
Stratification
  immature fish: 5 fish per 5-cm interval from 20 - 40 cm
  mature fish: 15 fish per 5-cm interval from 30 - 50 cm

Pacific cod

Two samples (collections) of each type given below will be made, with one each from Horseshoe and White Rocks.

Pre-cruise estimated length at 50% maturity = 56 cm (Westrheim 1977)

Fecundity sampling:

The length range to be sampled is 40 - 90 cm (50-cm range)
Total sample: 100 fish for each locality
Stratification:
  10 fish per 5-cm interval from 40 - 90 cm

Table 1 (cont'd)

Histology sampling:

The length range to be sampled is
  immature: 20 - 50 cm (30-cm range)
  mature: 40 - 90 cm (50-cm range)
Total sample: EACH LOCALITY
  immature fish: 15 fish
  mature fish: 80 fish
Stratification
  immature fish: 5 fish per 10-cm interval from 20 - 50 cm
  mature fish: 8 fish per 5-cm interval from 40 - 90 cm

Table 2. Number of English sole and Pacific cod, sampled for ovaries by selected length ranges.

English sole		Pacific cod	
length (cm)	N	length (cm)	N
Immature			
19.5 - 24.4	0	19.5 - 29.4	5
24.5 - 29.4	5	29.5 - 39.4	5
29.5 - 34.4	5	39.5 - 49.4	5
34.5 - 39.4	3		
Mature			
24.5 - 29.4	0	39.5 - 44.4	1
29.5 - 34.4	17	44.5 - 49.4	4
34.5 - 39.4	16	49.5 - 54.4	1
39.5 - 44.4	15	54.5 - 59.4	0
44.5 - 49.4	14	59.5 - 64.4	1

Table 3. Location of hydrographic station and water temperatures (°C) at standard depths (m) during FR/V W.E. RICKER cruise Nov. 25-29, 1986.

Haul no.	Date	Time (PST)	N. lat ° '	W. long ° '	Standard depths (m) 0	10	20	30	50	75	Bottom °C	Bottom Depth (m)
1	27	0934	53 43.7	130 48.6	9.1	9.0	8.9	8.9	8.9	8.9	8.9	84

Table 4. English sole histology sample collected from White Rocks on November 27 during FR/V W.E. RICKER cruise to Hecate Strait, November 25-29, 1986.

Maturity	Fork len. (cm)	Body wt. (g)	Ovary wt. (g)
Immature	27	176	0.8
Immature	27	176	0.7
Immature	28	202	0.4
Immature	28	195	1.1
Immature	29	225	1.9
Immature	30	255	0.2
Immature	31	293	1.6
Immature	31	270	1.2
Immature	32	315	1.0
Immature	33	351	3.5
Immature	36	466	2.4
Immature	36	429	1.9
Immature	36	399	1.9
Mature	31	293	0.9
Mature	32	325	1.2
Mature	33	336	1.7
Mature	33	340	1.8
Mature	33	331	4.0
Mature	33	357	1.0
Mature	33	300	0.7
Mature	33	328	3.7
Mature	34	357	1.3
Mature	34	42'	3.5
Mature	34	414	2.2
Mature	34	393	2.9
Mature	34	369	3.2
Mature	34	443	3.4
Mature	34	350	1.3
Mature	34	404	3.3
Mature	34	430	0.8
Mature	35	406	3.8
Mature	35	409	2.7
Mature	35	400	2.8
Mature	36	430	1.8
Mature	36	462	2.3
Mature	37	482	3.7
Mature	37	540	4.9
Mature	37	495	4.1
Mature	38	520	5.0
Mature	38	547	7.1

Table 4 (cont'd)

Maturity	Fork len. (cm)	Body wt. (g)	Ovary wt. (g)
Mature	38	550	4.4
Mature	38	505	2.9
Mature	39	562	5.0
Mature	39	587	5.1
Mature	39	580	4.4
Mature	39	530	4.9
Mature	40	652	9.9
Mature	40	673	7.2
Mature	40	630	6.0
Mature	41	669	6.5
Mature	41	682	7.6
Mature	41	667	3.5
Mature	42	695	6.5
Mature	43	733	8.5
Mature	43	723	7.1
Mature	43	795	10.3
Mature	43	764	7.1
Mature	43	857	6.3
Mature	44	756	8.3
Mature	44	742	6.5
Mature	44	746	7.4
Mature	45	899	11.2
Mature	45	834	8.5
Mature	45	811	6.7
Mature	45	851	9.9
Mature	45	855	8.8
Mature	45	818	9.5
Mature	46	966	10.3
Mature	46	975	12.5
Mature	46	894	5.5
Mature	46	986	8.5
Mature	46	849	13.8
Mature	46	914	8.6
Mature	46	834	8.8
Mature	47	926	9.7

Table 5. Pacific cod histology sample collected from White Rocks on November 27 during FR/V W.E. RICKER cruise to Hecate Strait, November 25-29, 1986.

Maturity	Fork len. (cm)	Body wt. (g)	Ovary wt. (g)
Immature	28	222	1.6
Immature	28	207	0.1
Immature	28	207	1.5
Immature	29	256	0.8
Immature	29	248	0.6
Immature	31	354	1.3
Immature	32	341	2.0
Immature	33	366	1.3
Immature	35	460	1.8
Immature	36	488	2.8
Immature	41	750	2.7
Immature	42	833	3.3
Immature	44	953	4.9
Immature	47	1212	6.0
Immature	50	1375	6.6
Mature	40	640	3.2
Mature	45	1010	33.1
Mature	46	1046	16.4
Mature	47	1046	5.4
Mature	48	1126	6.8
Mature	50	1182	6.7
Mature	61	2851	67.6

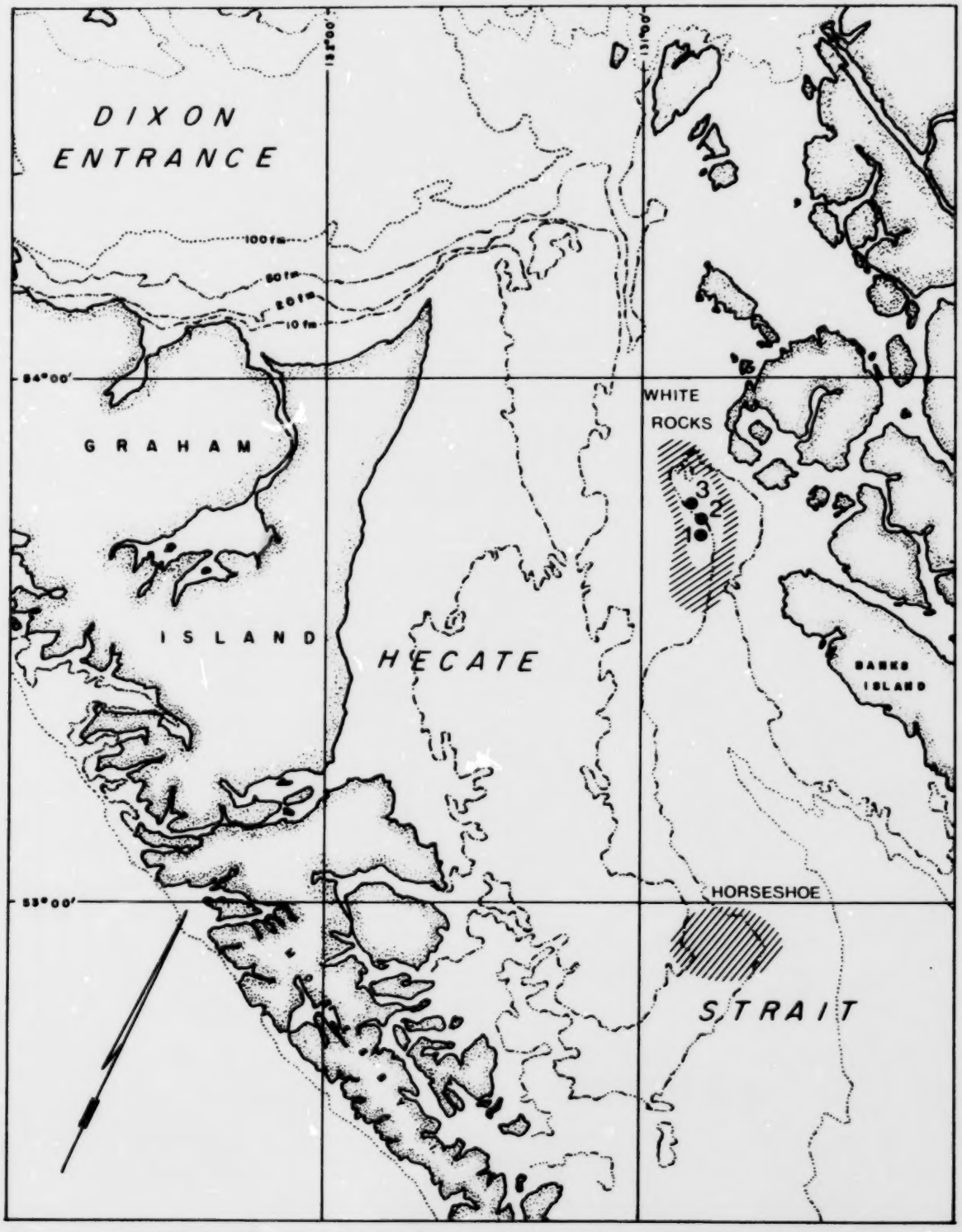
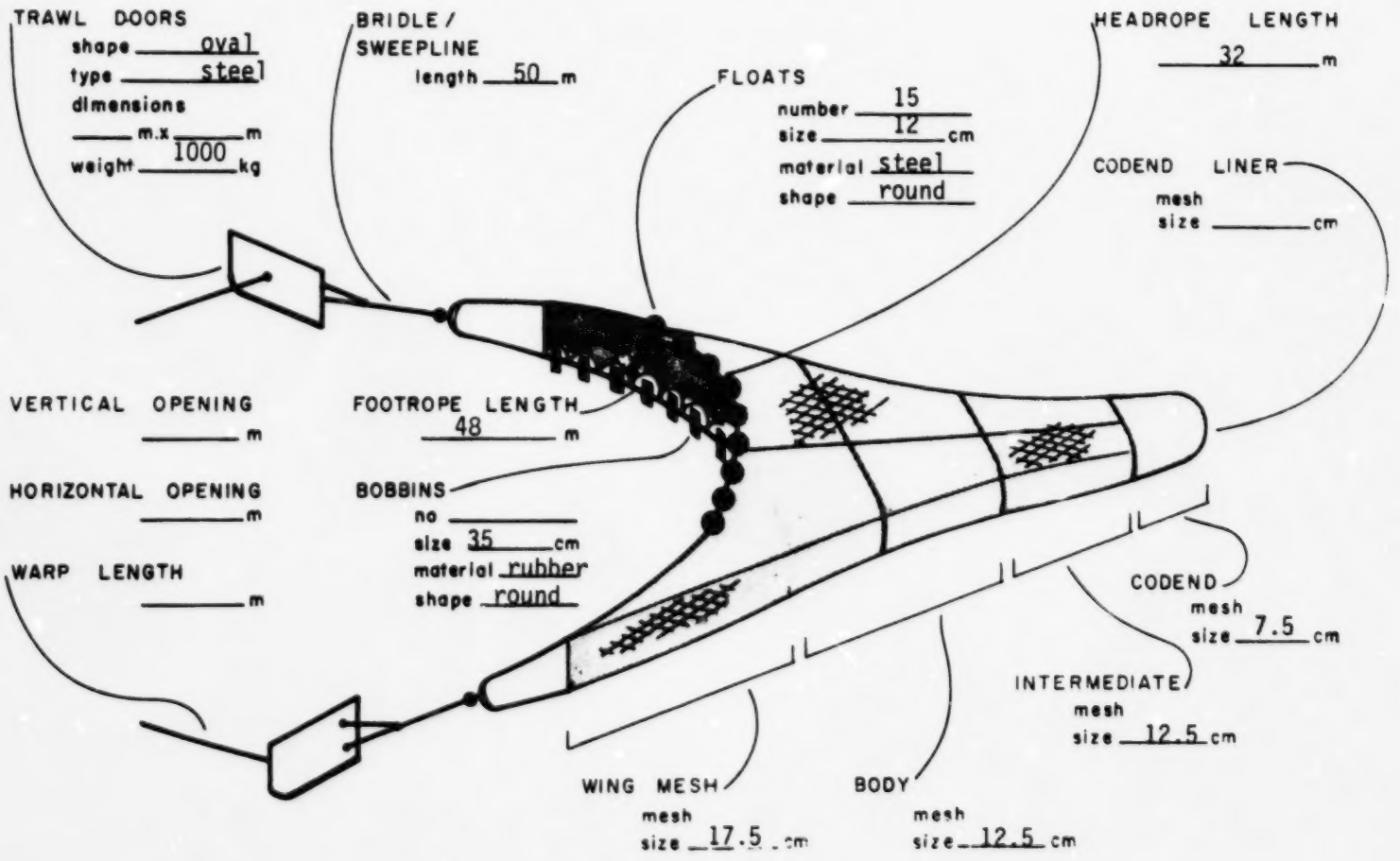


Fig. 1. Locations of trawl hauls for FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

Fig. 2. NET DIMENSIONS AND CHARACTERISTICS FOR BOTTOM TRAWL

VESSEL FR/V W.E. RICKER NET Engel 145

OBSERVATION PERIOD Nov. 25-29, 1986



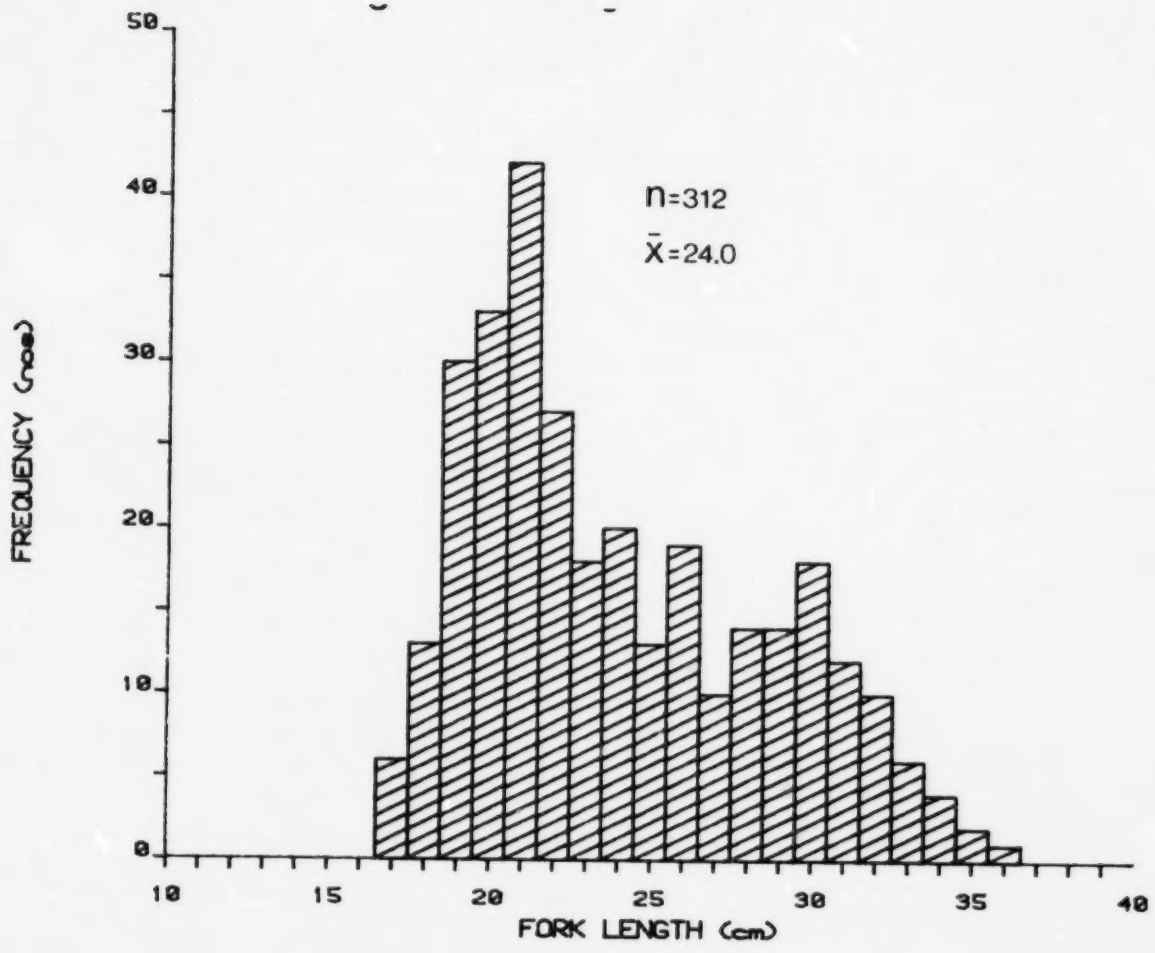


Fig. 3. Length frequency for English sole males caught (hauls 1,2) at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

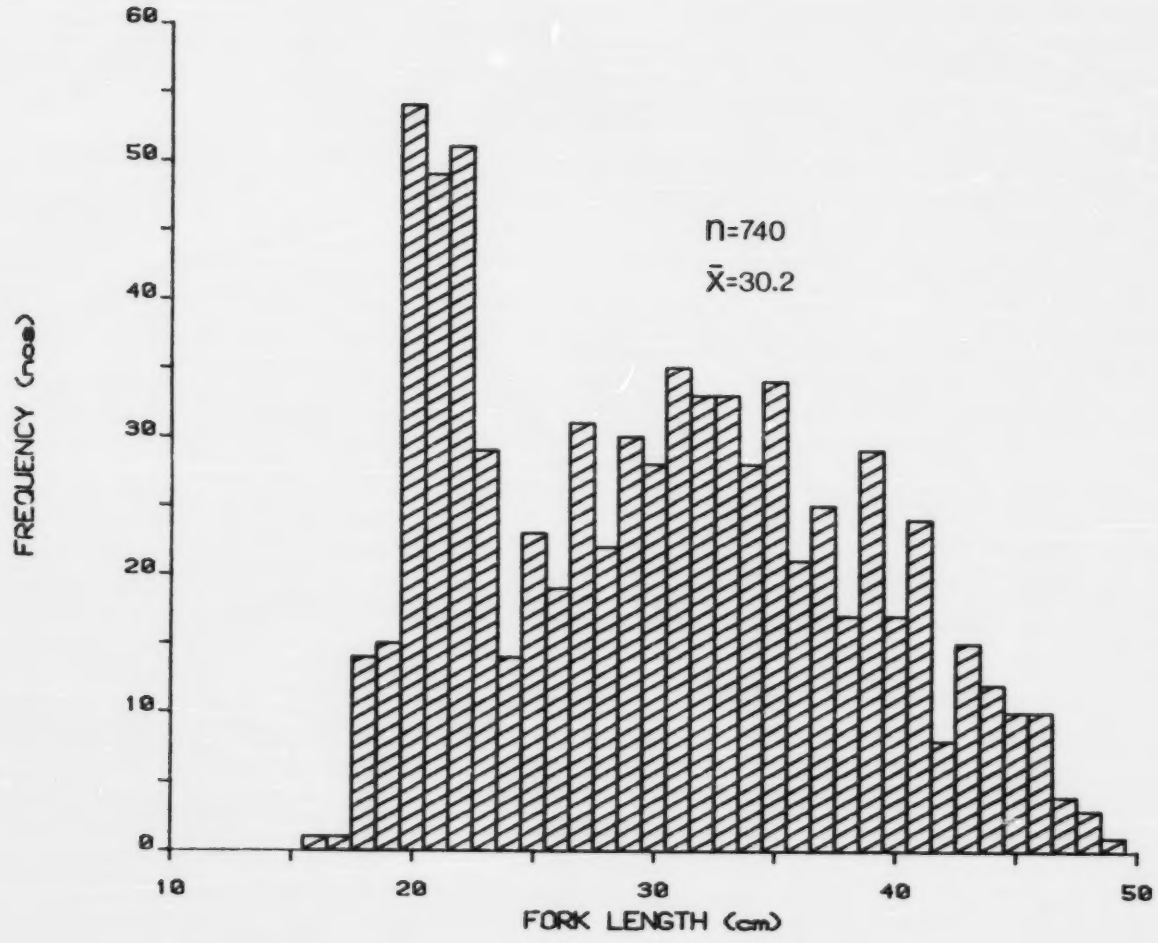


Fig. 4. Length frequency for English sole females caught (hauls 1,2) at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

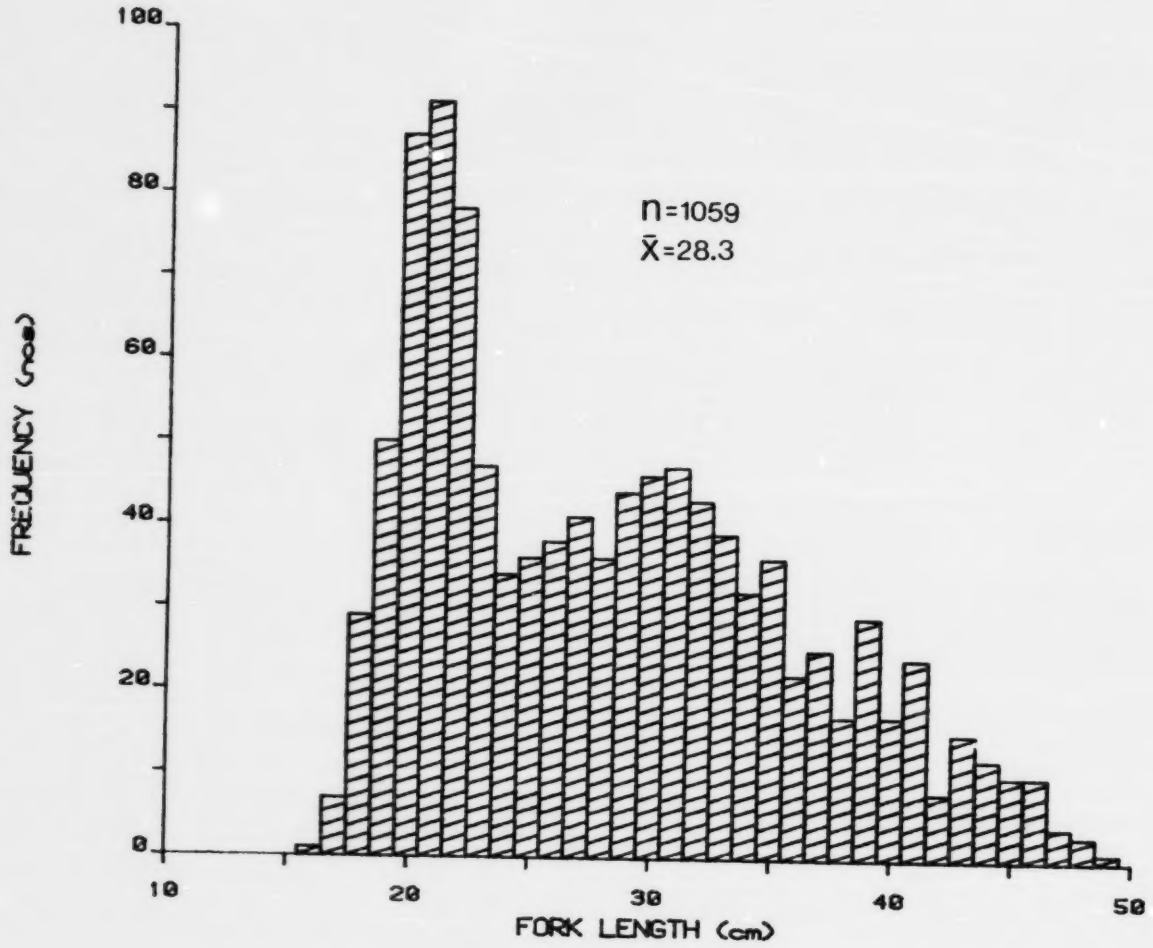


Fig. 5. Total length frequency for English sole caught (hauls 1, 2) at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

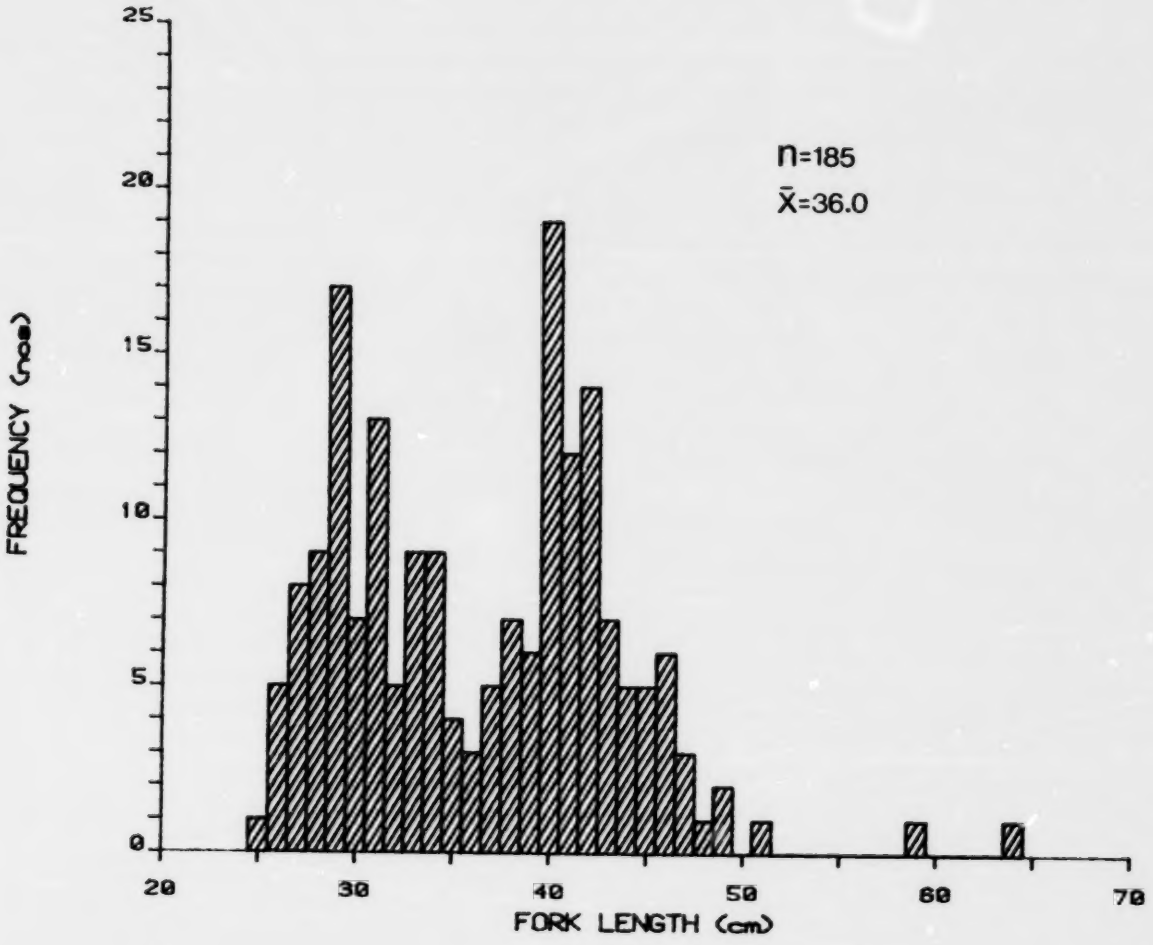


Fig. 6. Length frequency for Pacific cod males caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

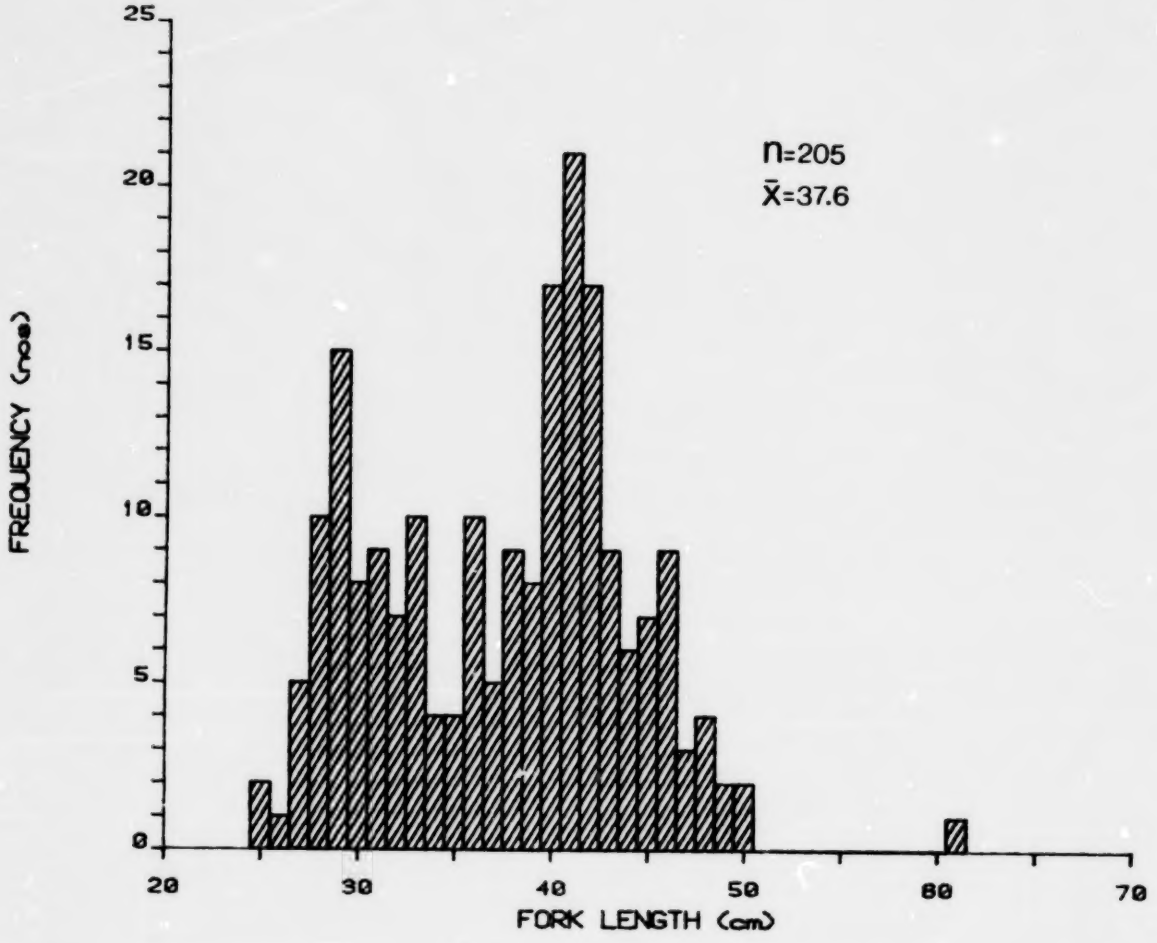


Fig. 7. Length frequency for Pacific cod females caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

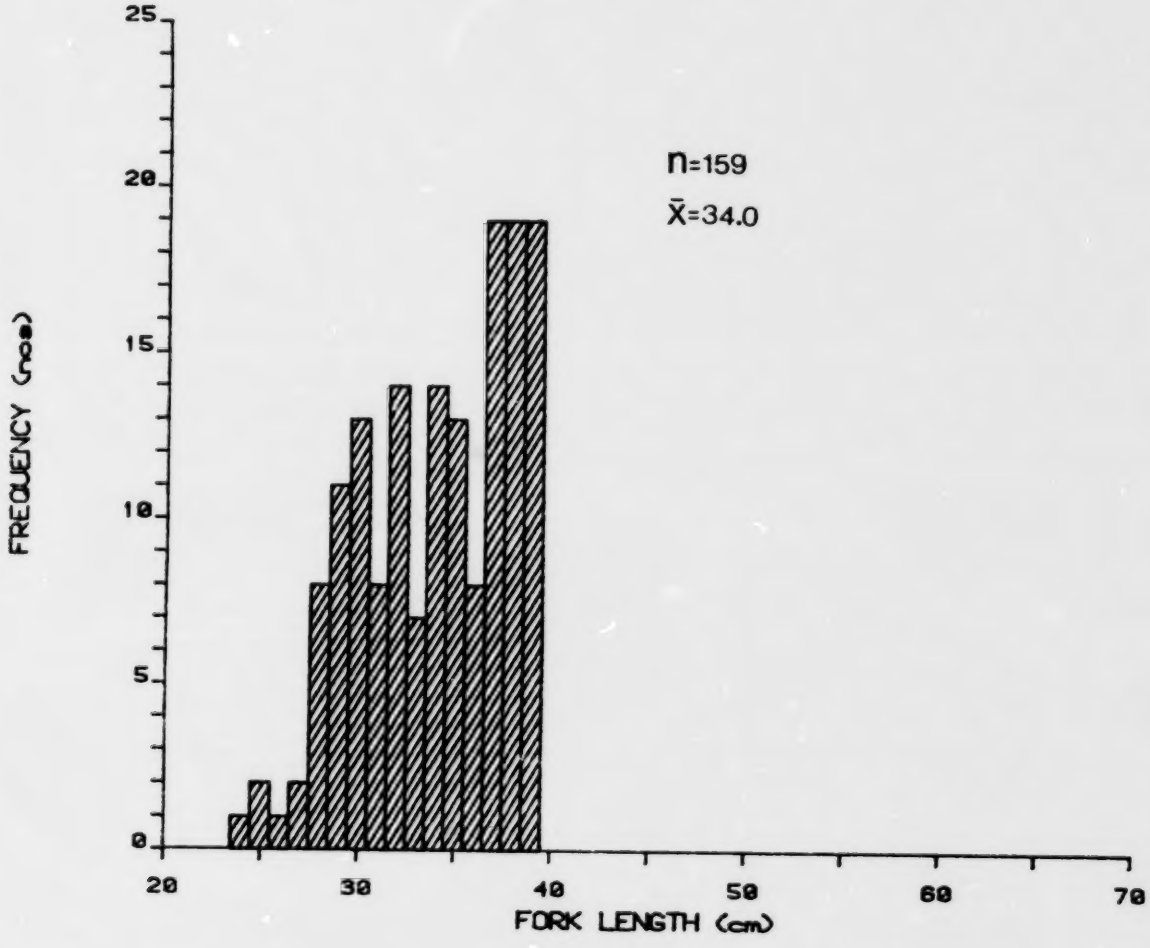


Fig. 8. Length frequency for Pacific cod unsexed caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

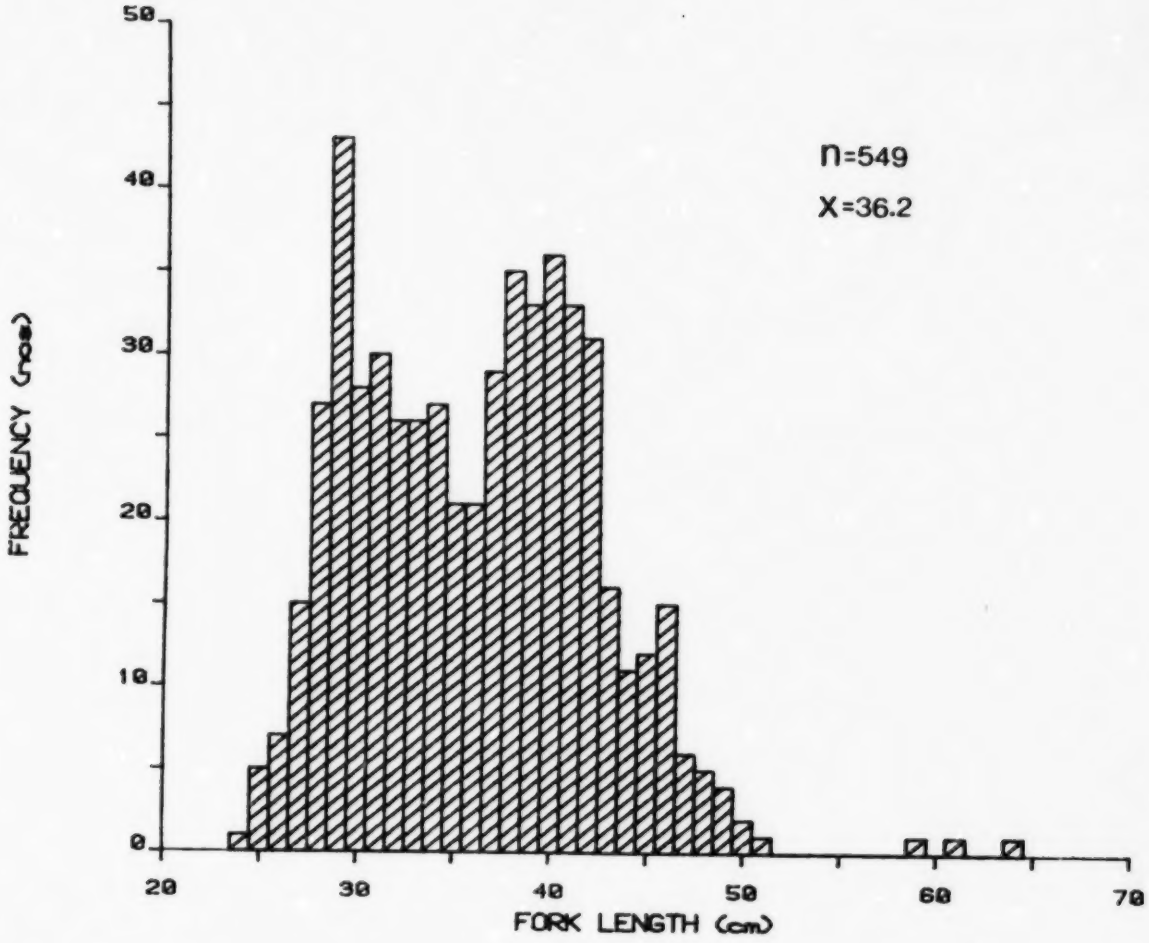


Fig. 9. Total length frequency for Pacific cod caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986.

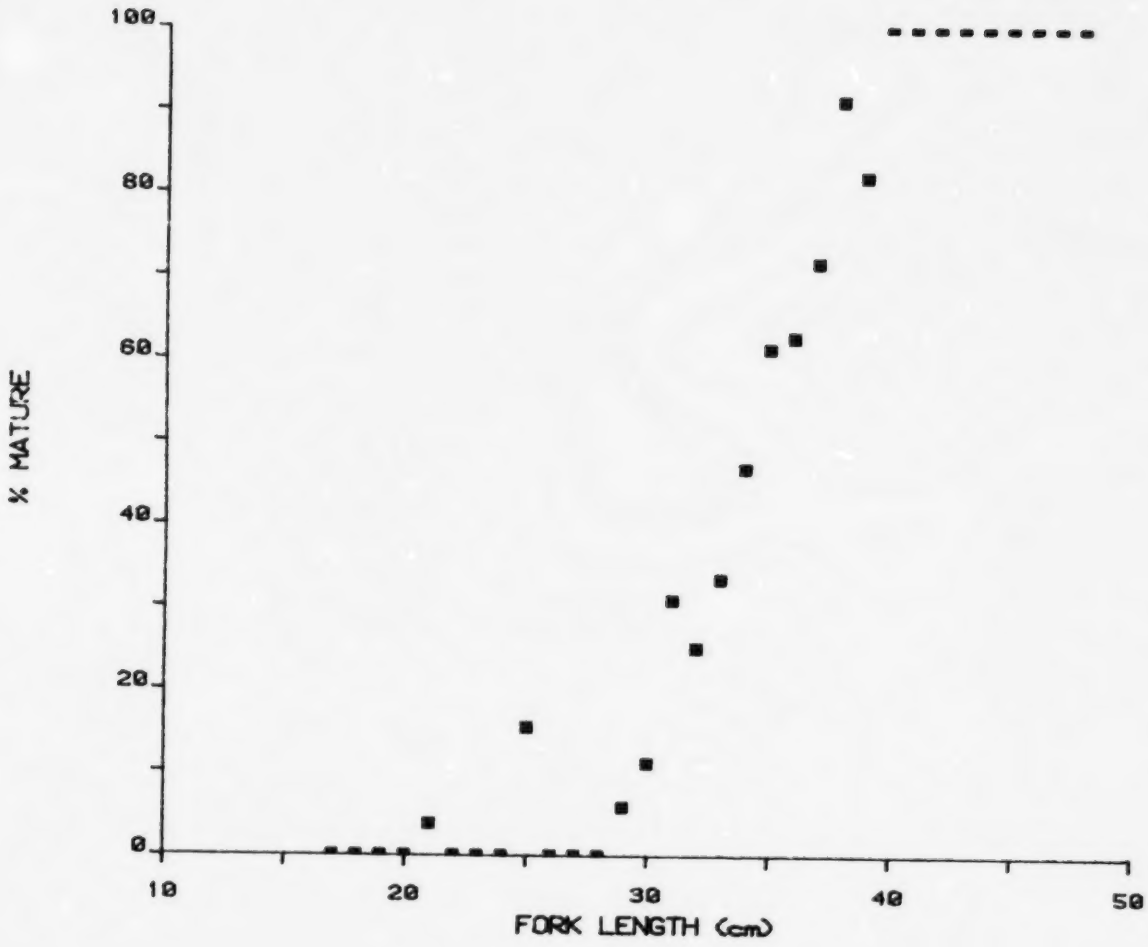


Fig. 10. Maturity ogive for English sole females caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait, November 25-29, 1986. The length at 50% maturity is 34.3 cm, based on a least squares fit on percentage mature in the range of 10% to 90%, length range 30 to 39 cm (Y=28.7+11.2x, where y is length and x is percentage).

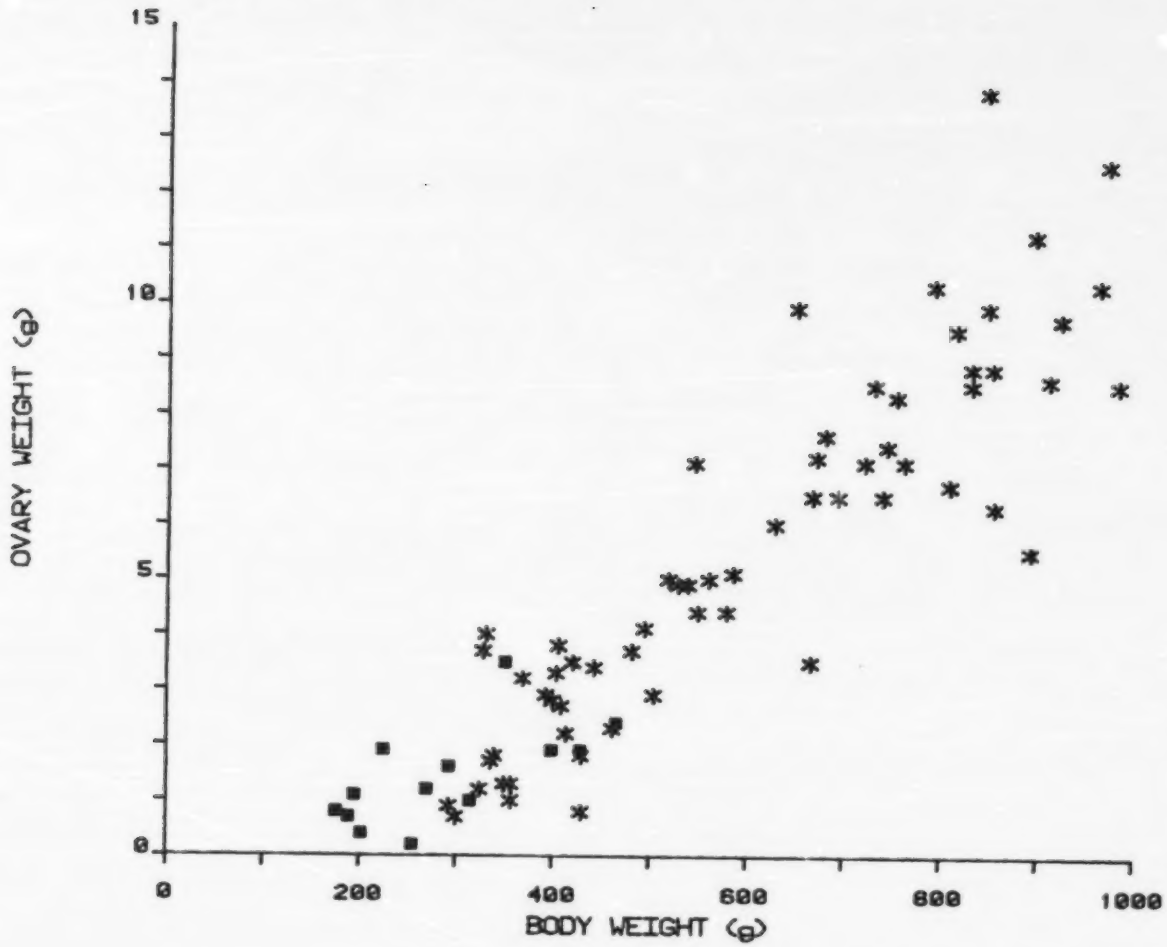


Fig. 11. Relationship between ovary weight and body weight for English sole caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait. (*=mature,■=immature)

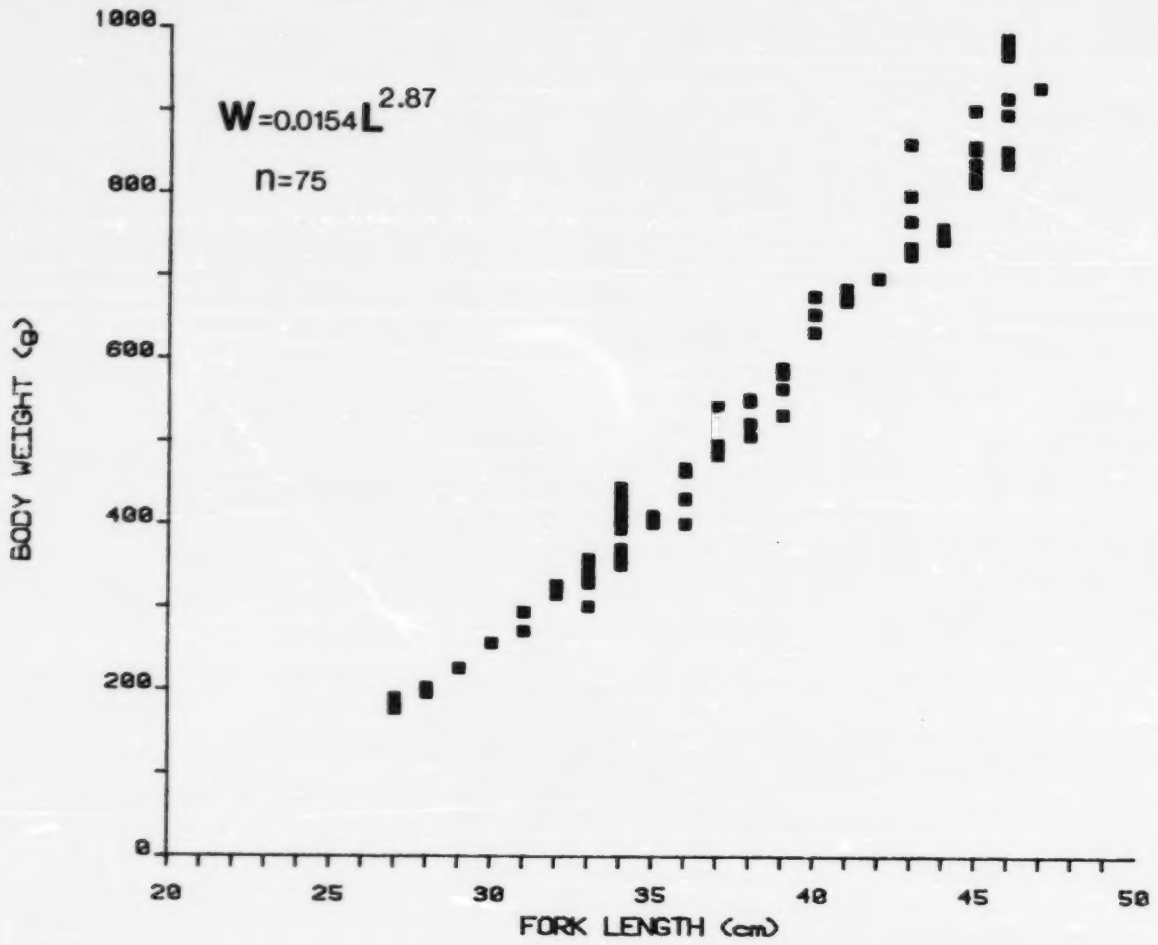


Fig. 12. Relationship between body weight and fork length for English sole females caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait. (*=mature, ■=immature)

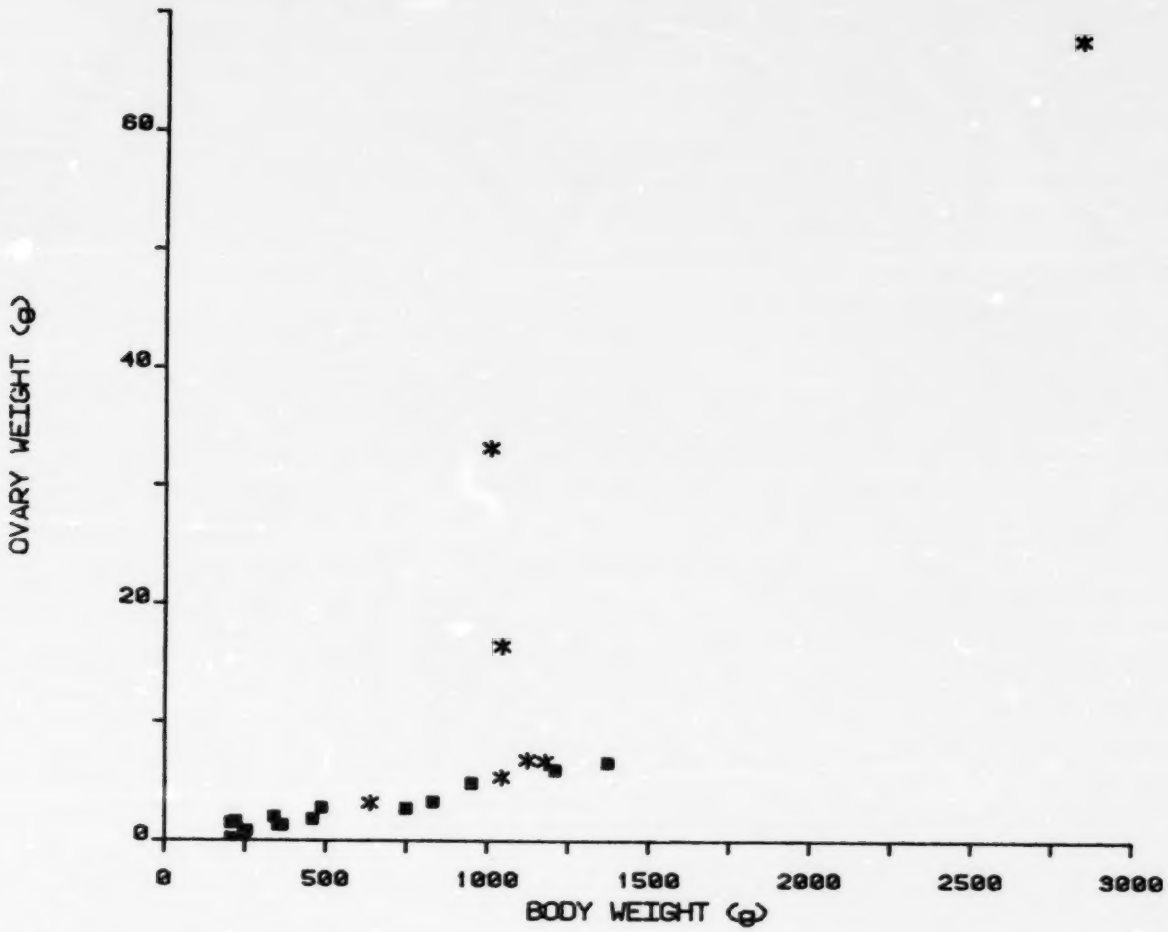


Fig. 13. Relationship between ovary weight and body weight for Pacific cod caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait. (*=mature,■=immature)

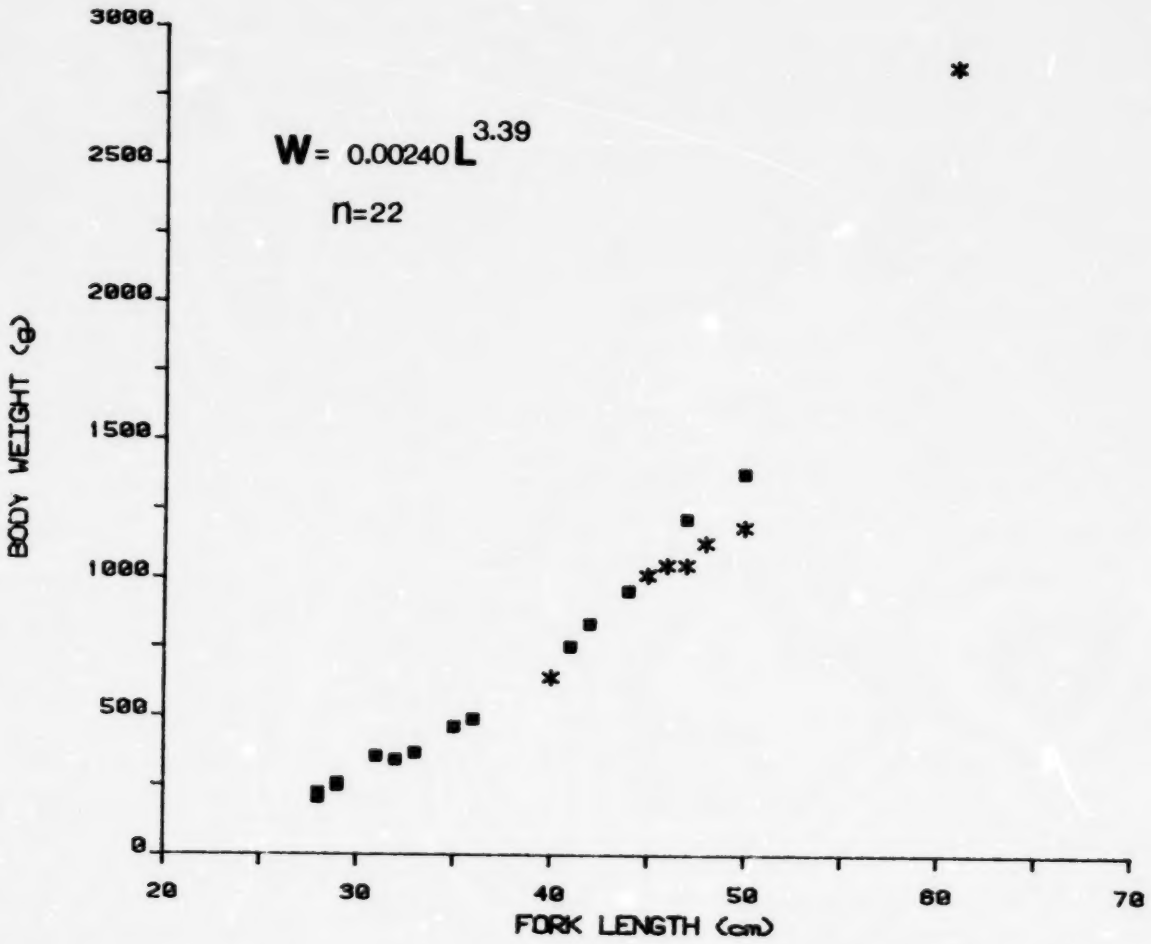


Fig. 14. Relationship between body weight and fork length for Pacific cod females caught at White Rocks on FR/V W.E. RICKER reproductive-biology cruise to Hecate Strait. (*=mature,■=immature)

Appendix table 1. Bridge log for FR/V W. E. RICKER cruise for studies on the reproductive biology of Pacific cod and English sole in Hecate Strait Nov. 25-29, 1986.

Haul number		1	2	3
Date		Nov. 27	Nov. 27	Nov. 27
Area (Major, Minor)		8,05	8,05	8,05
Start Time (PST)		0934	1139	1343
Duration (MIN)		20	20	9
Start N. Lat.	(DEG)	53°	53°	53°
	(MIN)	43.7'	43.0'	43.8'
W. Long.	(DEG)	130°	130°	130°
	(MIN)	48.6'	47.2'	47.5'
Start Loran-C	X	11976.2	11985.8	11978.7
	Z	41658.2	41657.9	41660.1
Finish N. Lat.	(DEG)	53°	53°	53°
	(MIN)	42.7'	43.9'	44.1'
W. Long.	(DEG)	130°	130°	130°
	(MIN)	47.3'	48.9'	47.8'
Finish Loran-C	X	11988.5	11972.6	11975.3
	Z	41656.7	41658.6	41660.5
Haul Distance	(KM)	2.3	3.3	0.7
	(N MI)	1.4	2.0	0.4
Direction (DEG. TRUE)		134	330	330
Bottom Depth	(M)	84.2	99.9	107
	(FM)	42	50	54
Modal Depth	(M)	86.7	91.4	108
Water Temp.	(DEG C)	9.1		
Temp. Depth	(M)	surface		
Gear Type		Engel 145	Engel 145	Engel 145
Remarks				Short tow due to main winch failure